PLAY ANALYSIS OF THE CANE CREEK SHALE, PENNSYLVANIAN PARADOX FORMATION, PARADOX BASIN, SOUTHEAST UTAH

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PANEL ONE

ABSTRACT

The Cane Creek shale is a transgressive-regressive sequence in the lower portion of the Pennsylvanian Paradox Formation, Paradox Basin, southeast Utah. The Cane Creek is tens of feet to nearly 200 feet thick, over- and underlain by beds of salt, and divided into A, B, and C intervals (in descending order). The B interval is the primary hydrocarbon source rock and productive zone consisting of black organic-rich shale, dolomite, dolomitic siltstone, and some anhydrite. Significant porosity (up to 15%) is found in the dolomite and dolomitic siltstone, but permeability is generally low (~0.1 mD); naturally occurring fractures are necessary for economic production. The A and C intervals, mostly dolomite and dolomitic siltstone, are the seals for the B interval, helping prevent fracture communication with the adjacent salt beds.

Oil production was first established from the Cane Creek shale in the 1960s. Horizontal drilling renewed the play in the 1990s, but development is slow due to difficult terrain, as well as complex stratigraphy and structure. Six fields have produced over 5.4 million barrels of oil, only a small fraction of the U.S. Geological Survey's estimated undiscovered recoverable oil reserves in the Cane Creek and other Paradox Formation shale beds.

The Utah Geological Survey is conducting a multi-year, U.S. Department of Energy-funded study of the shale oil potential of the Cane Creek. In support of our study, operators have provided core and extensive core analyses which we will display, along with regional play mapping and evaluation.

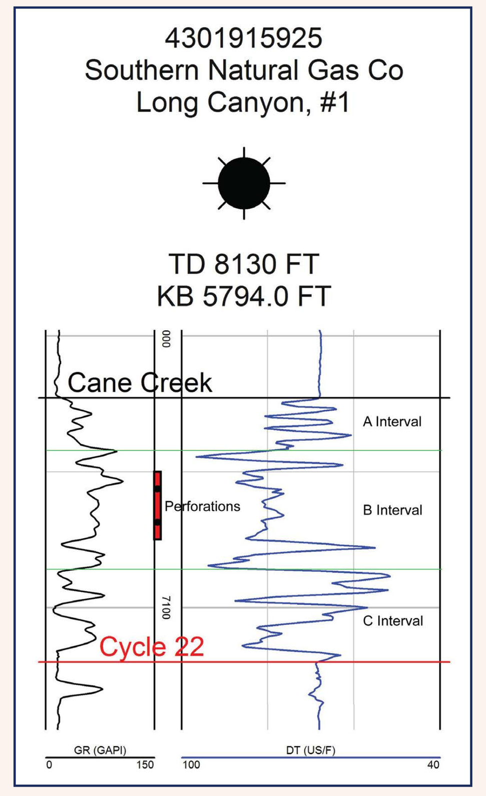
ACKNOWLEDGEMENTS

Project funded by: U.S. Department of Energy – National Energy Technology Laboratory and Utah Geological Survey.

Core, data, and insightful technical discussion has been provided by Fidelity Exploration & Production Company, an MDU Resources Group Company. The Cisco State 36-13 core and data were donated by Castleton Commodities, Inc. (CCI).

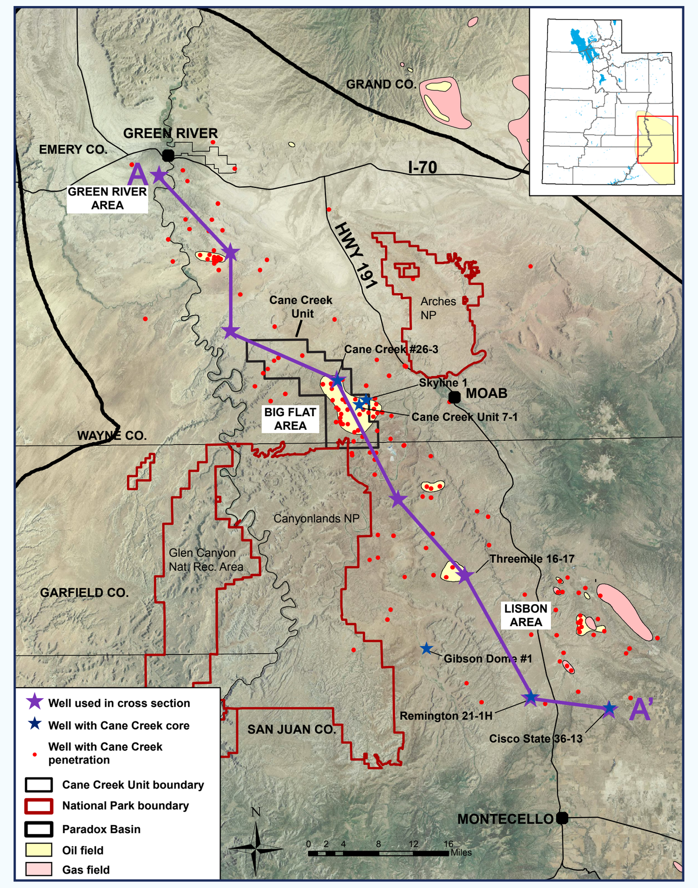
Poster design and graphic artistry by Elizabeth Firmage, Utah Geological Survey Editorial Staff.

TYPE LOG

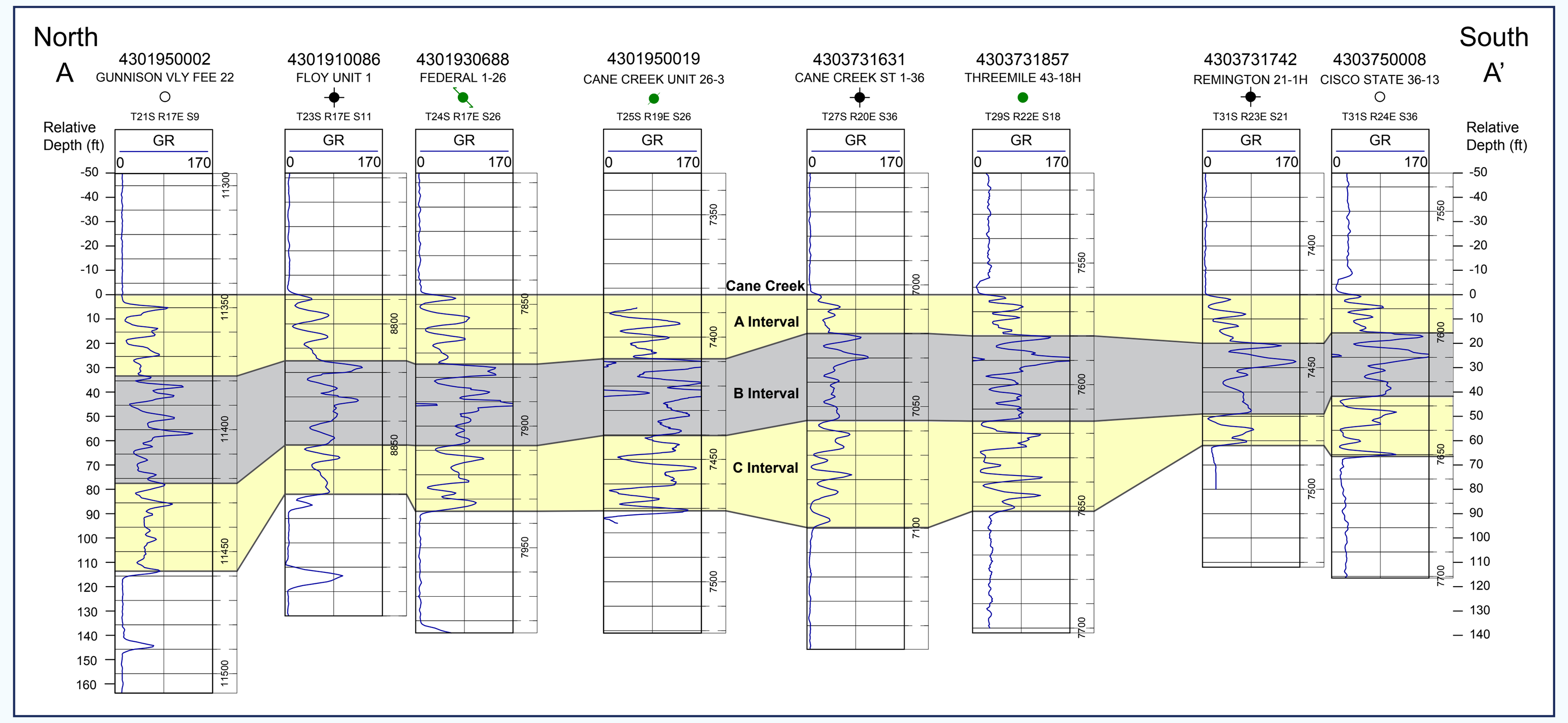


Cumulative production through April 2014
1,124,445 BO
1,161,798 MCFG
566,863 BW

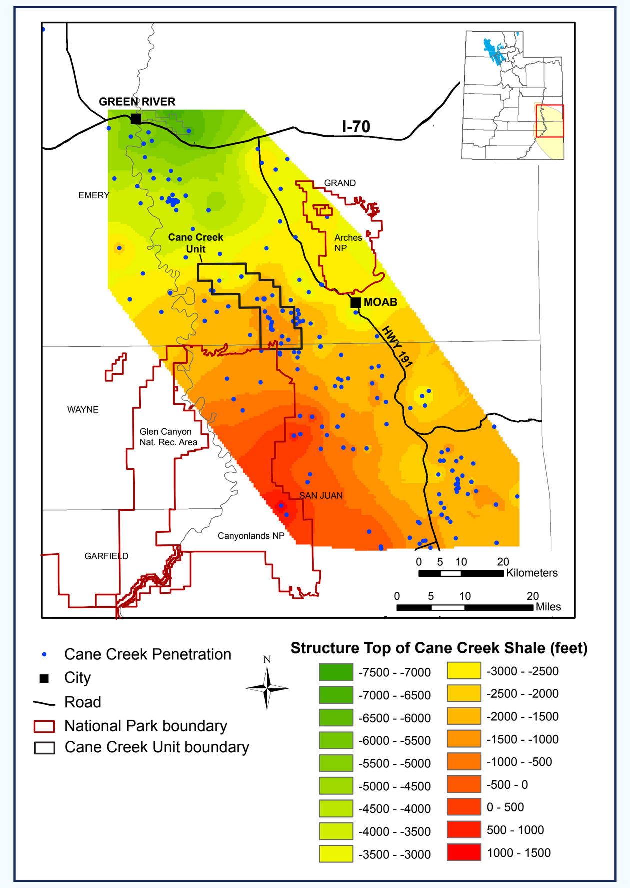
REGIONAL MAPPING



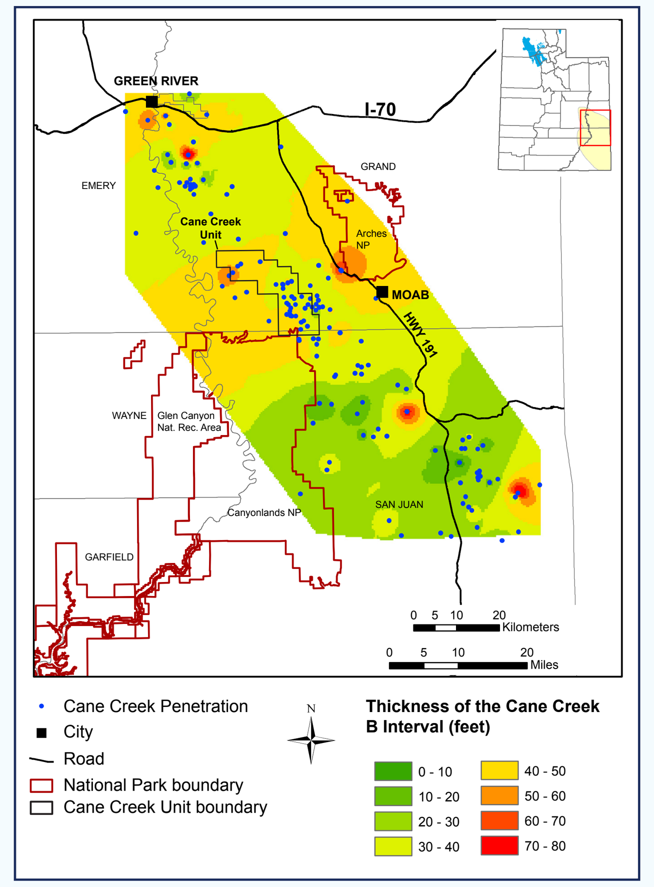
Location of cores and cross section



North-to-south stratigraphic cross section of the Cane Creek shale

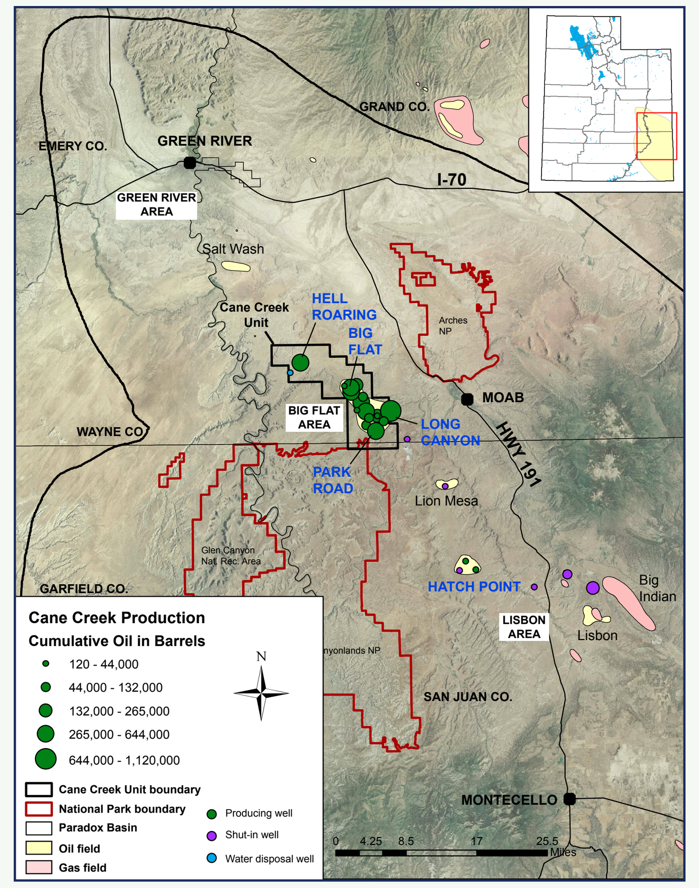


Cane Creek structure



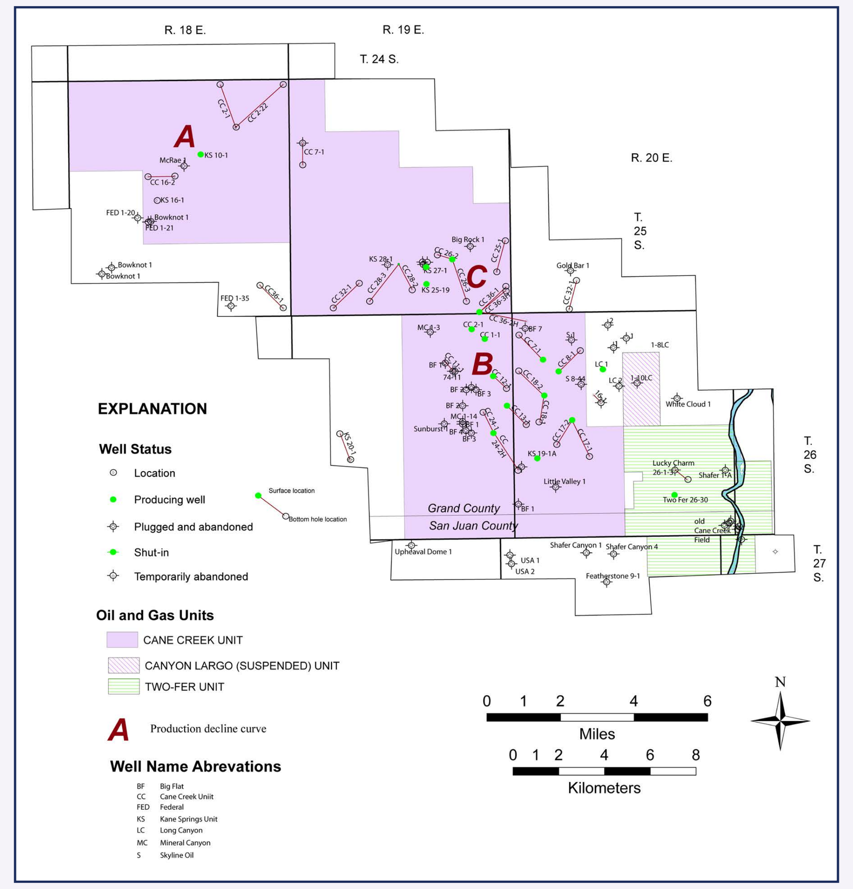
Thickness of the Cane Creek B interval, the primary reservoir target

PRODUCTION

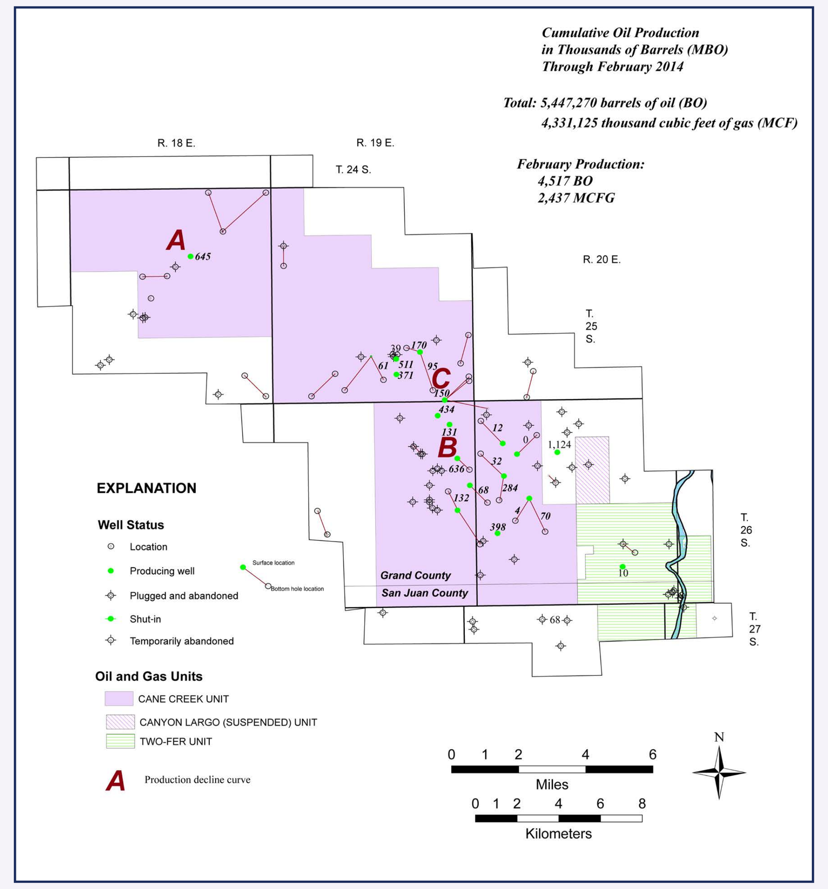


Cumulative oil production from the Cane Creek shale

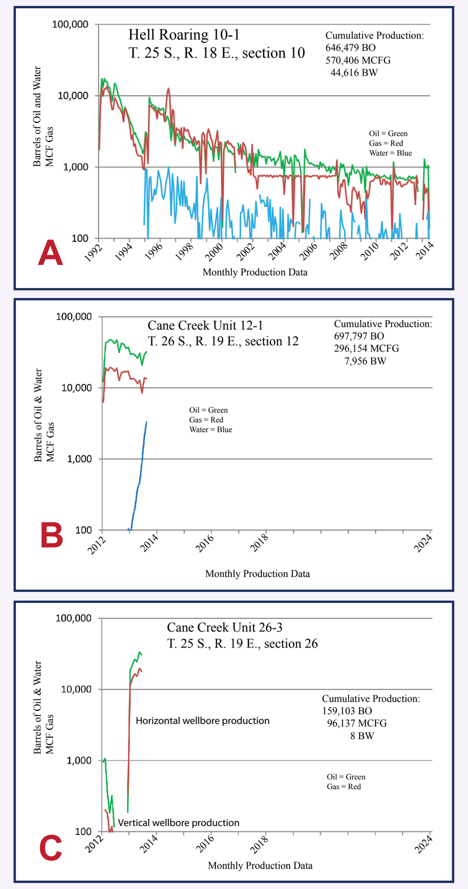
CANE CREEK UNIT & PRODUCTION



Cane Creek Unit

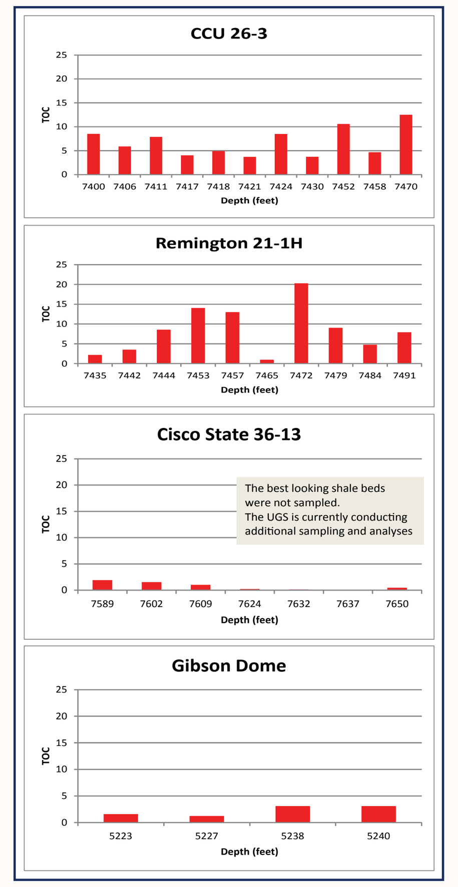


Oil production from the Cane Creek Unit and neighboring wells

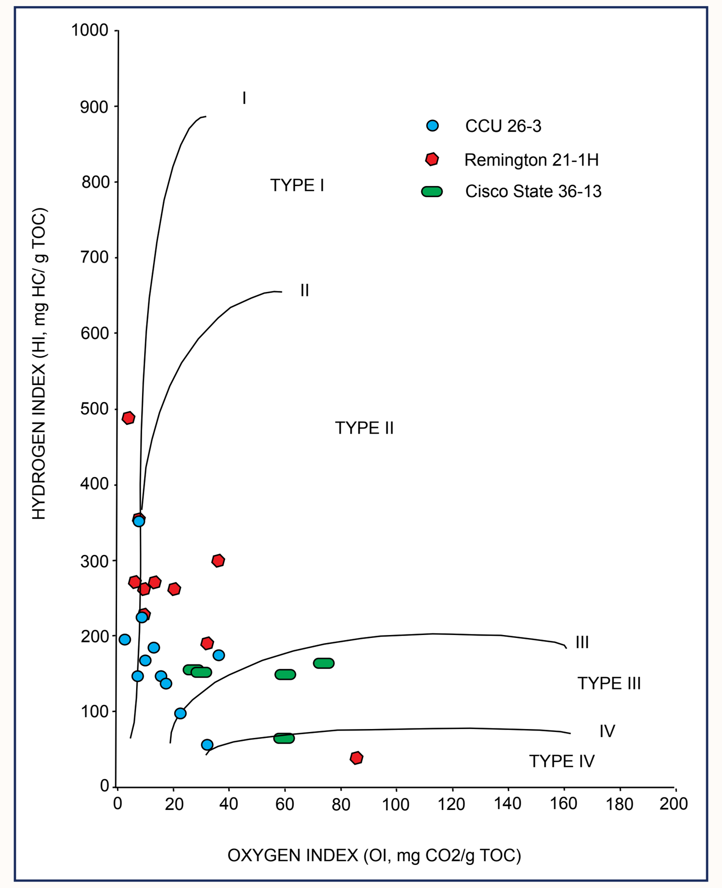


Production decline curves from three wells

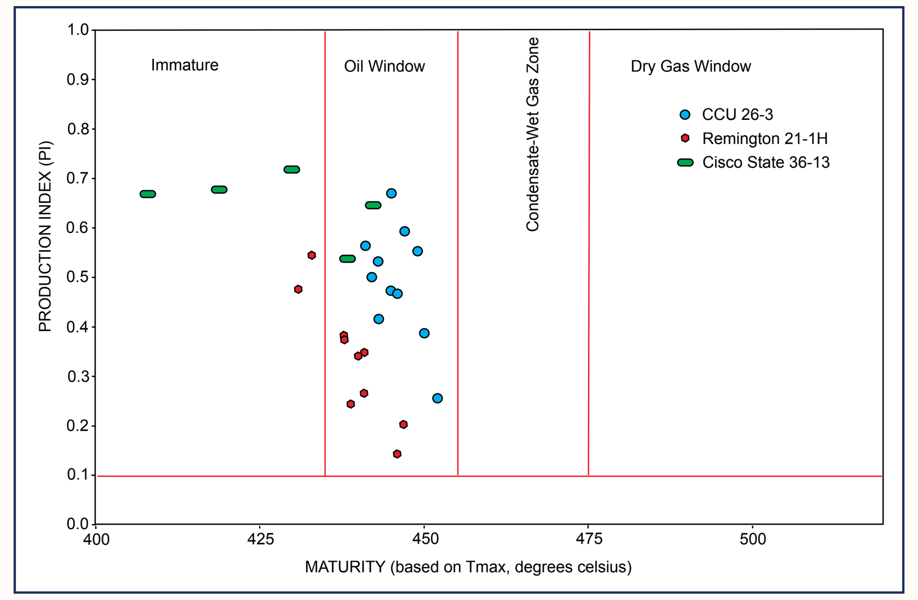
GEOCHEMISTRY



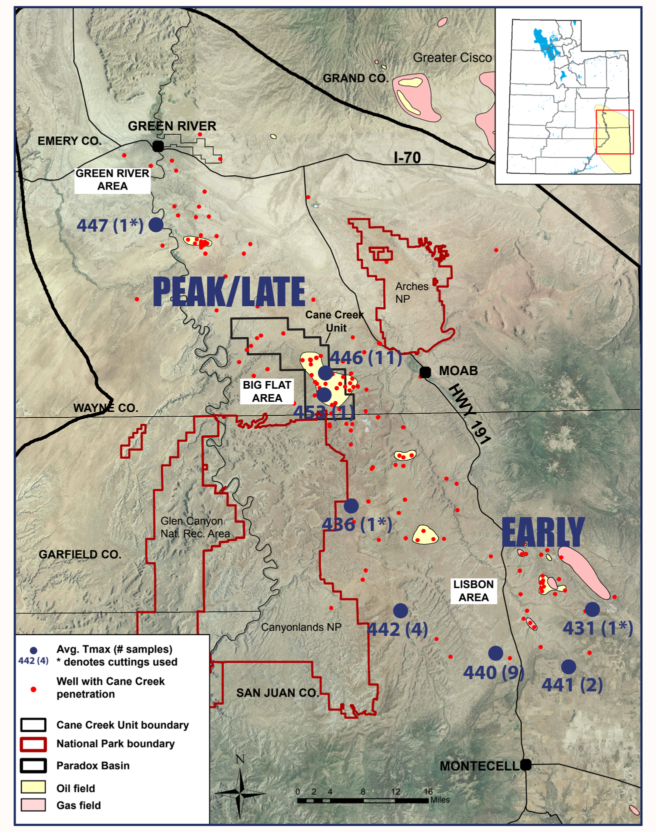
Total organic carbon (TOC) from four Cane Creek cores



Kerogen type from three Cane Creek cores

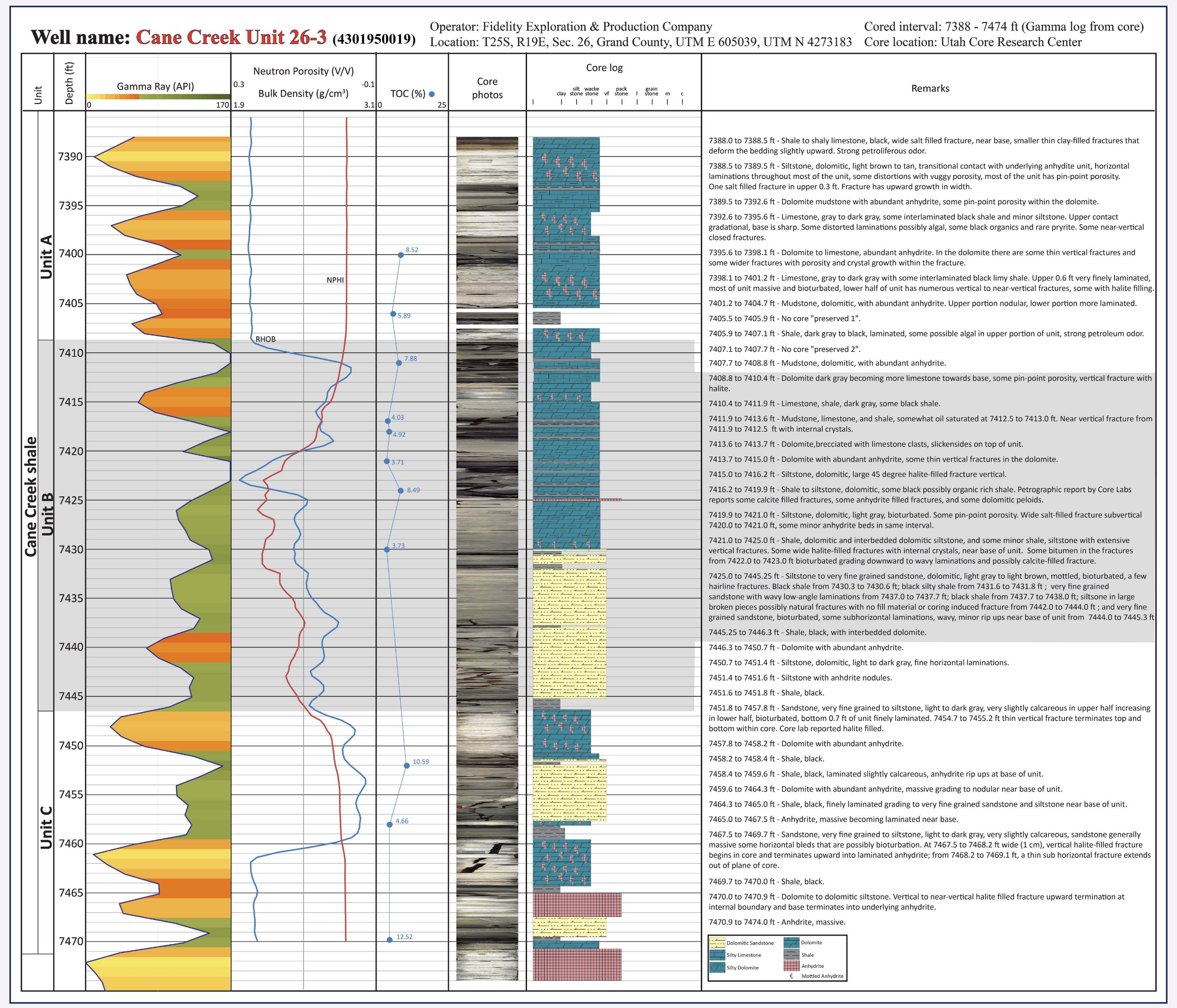


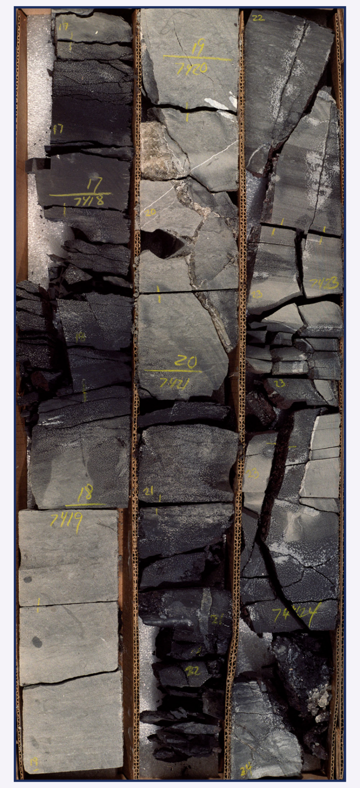
Maturity (based on Tmax) and production index from three Cane Creek cores



Tmax values from the Cane Creek shale
Early Tmax 435–445°C
Peak Tmax 445–450°C
Late Tmax 450–470°C

CANE CREEK UNIT 26-3
T. 25 S., R. 19 E., Section 26

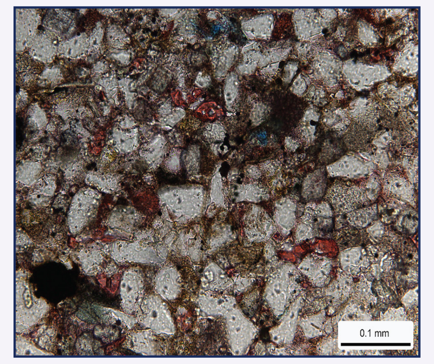




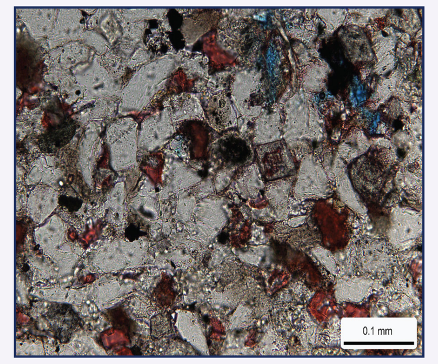
7418–7424 ft

7425–7432 ft

Core photography by Triple O Slabbing, Denver, CO., provided by Fidelity Exploration & Production Company

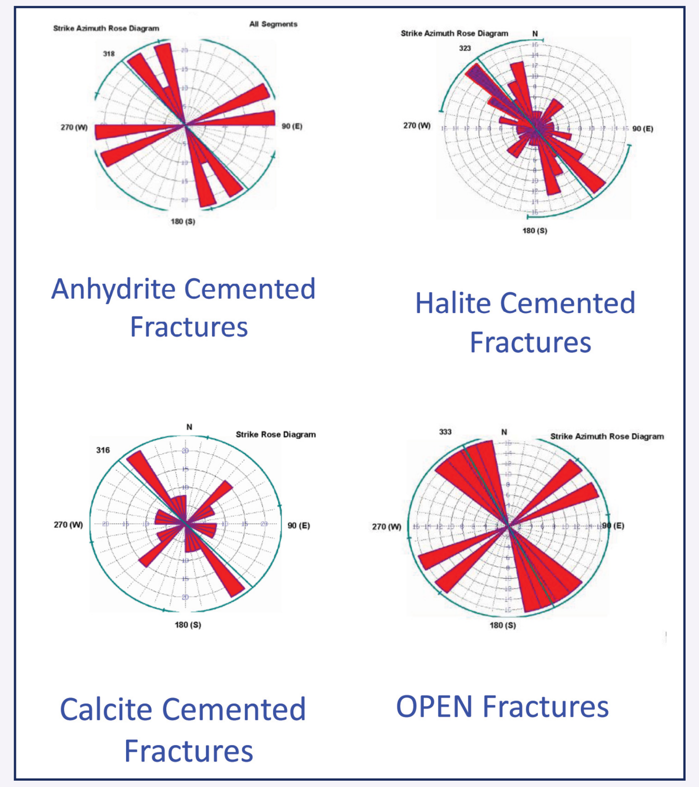


Depth: 7429 ft
Argilaceous Sandstone: Quartz, feldspar, dolomite and calcite cement
Porosity: 12%
Permeability: 0.11 mD



Depth: 7431 ft
Argilaceous Sandstone: Quartz, feldspar, dolomite rock fragment, dolomite and calcite cement
Porosity: 11%
Permeability: 0.14 mD

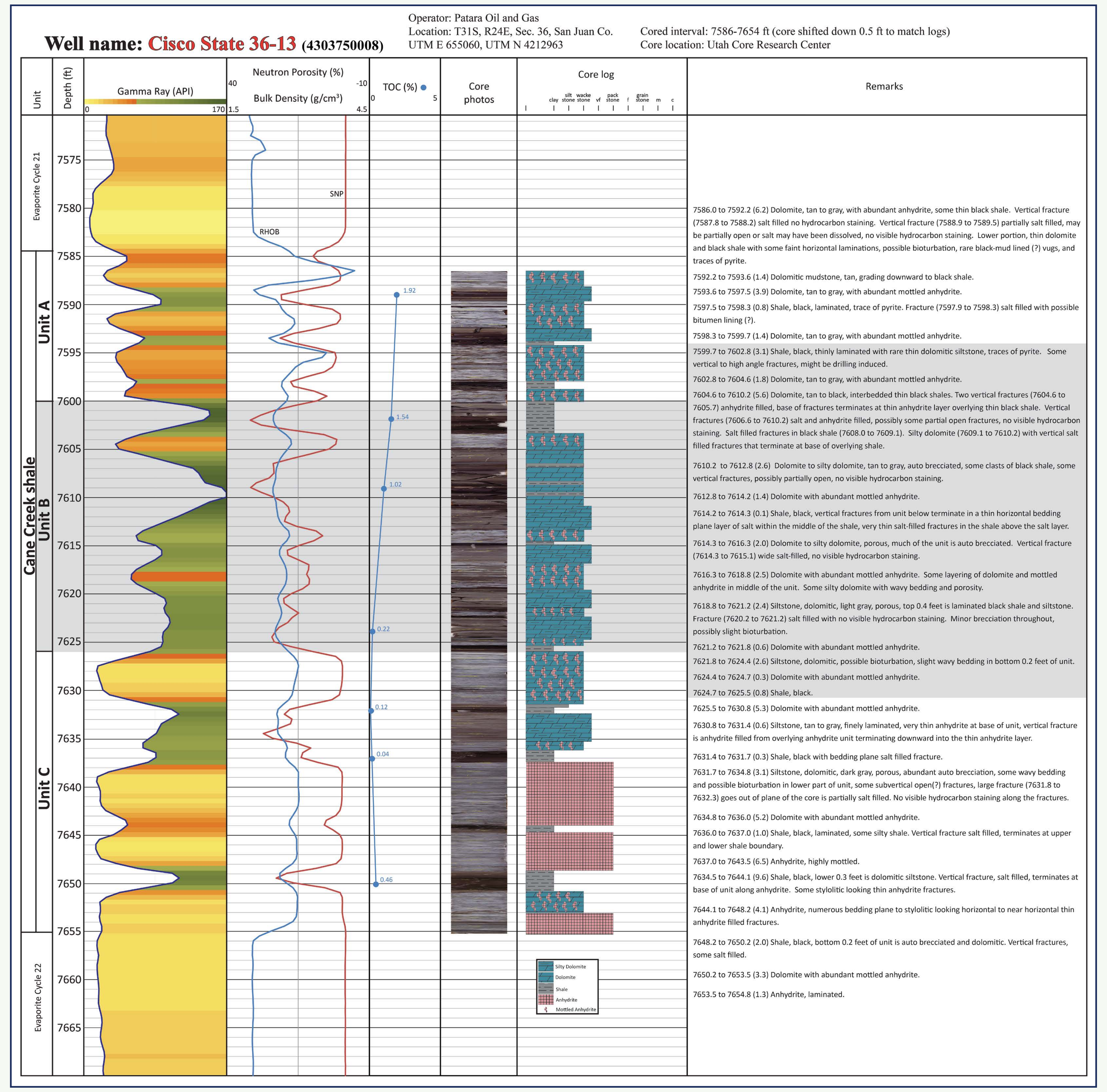
Thin section photos and descriptions by Core Laboratories, provided by Fidelity Exploration & Production Company



Cane Creek Unit 26-3 fracture study by Core Laboratories

Provided by Fidelity Exploration & Production Company

CISCO STATE 36-13
T. 31 S., R. 24 E., Section 36

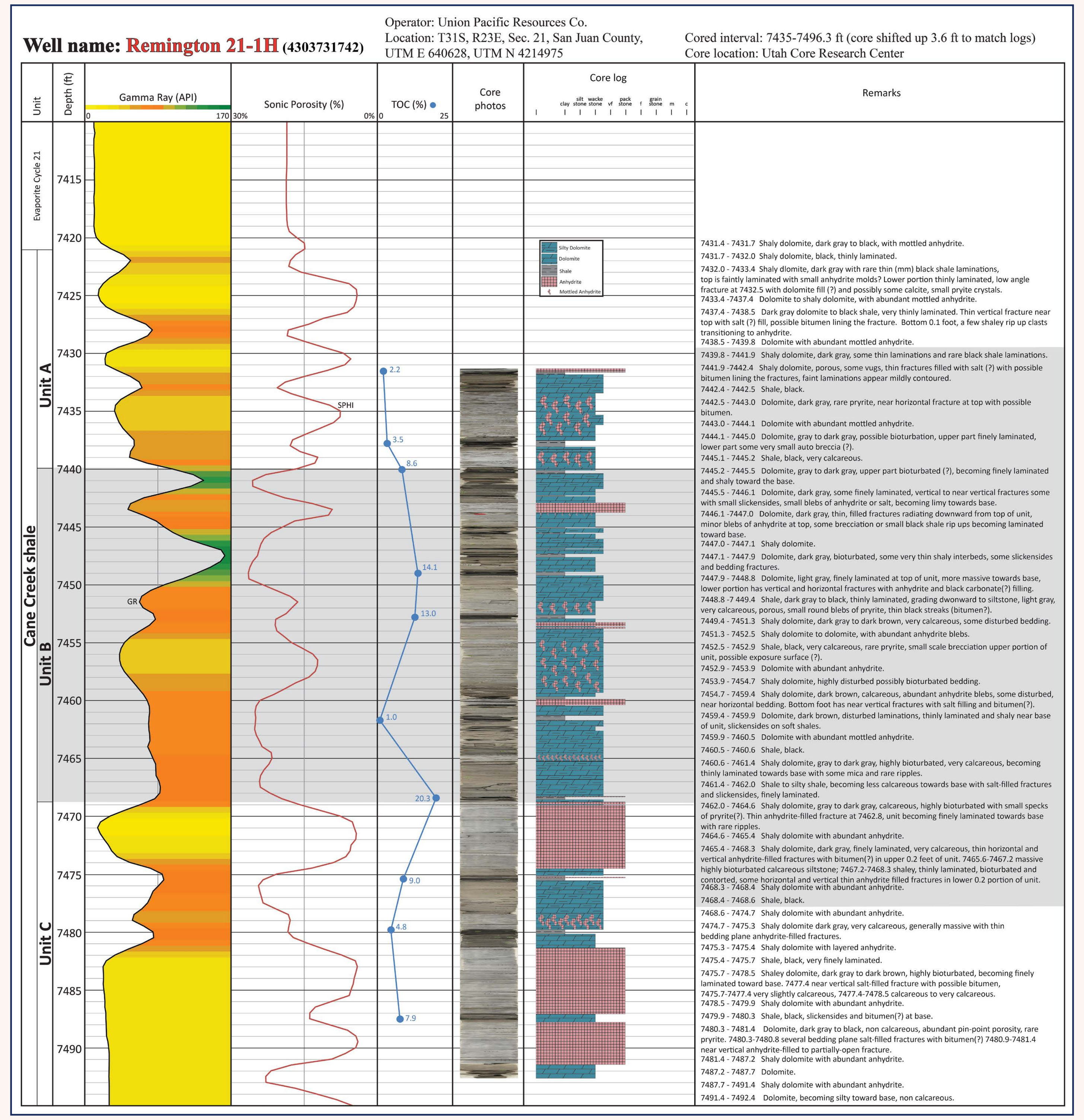


7601–7608 ft

7608–7615 ft

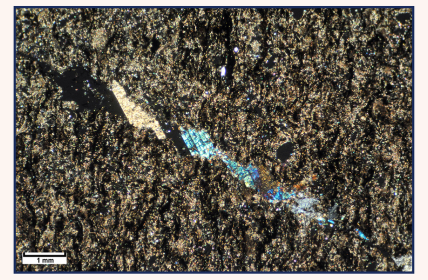
Core photography by Triple O Slabbing, Denver, CO., CCI

REMINGTON 21-1H
T. 31 S., R. 23 E., Section 21

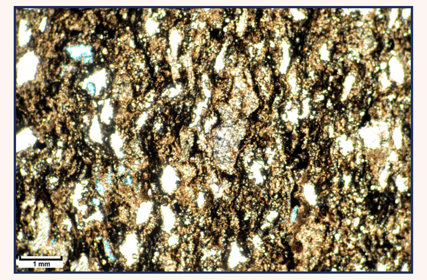


7471–7474 ft

7479–7482 ft



Depth: 7480 ft
Dolomite: Wavy matrix consisting of dolomite crystals, quartz crystals, and dark brown clay minerals. Detrital feldspar and quartz showing dissolution and compaction fractures. Edge oriented biotite or mica crystals in matrix and near fracture. Light brown to tan rock fragment of dissolved silica cement with suboriented crystals to matrix orientation. Subrounded pores in matrix filled with rim crystals in a silica cement. Silica cement shows fluid and crystal inclusions. Clustered anhydrite crystals filling open fracture with silica cement embayments.



Depth: 7481 ft
Dolomite: Waxy, quartz, and clay mineral matrix. Pore space shown with blue (blue epoxy). Subrounded white pore spaces filled with silica cement. Pore spaces contain secondary rim crystals of calcite and dolomite. Larger detrital quartz and feldspar crystals show compaction fractures and desorption. Fractured calcite crystal in center of photograph contains fluid inclusions and inclusions.

PANEL TWO

RESERVOIR PROPERTIES

- Lithology: Dolomitic siltstone to fine-grained sandstone with interbedded organic-rich shale and dolomitic mudstone with anhydrite
- Porosity: 6 to 12%
- Permeability: matrix <0.1 mD, with fractures 39 to 400 mD*
- Initial Reservoir Pressure Gradient: 0.85 to 0.94 psi/ft*
- Gas to Oil Ratio: 745 to 850 CFG/BO*

*Grove and others 1993

STRUCTURE & FRACTURES

- Faulted anticline Late Mississippian to Early Pennsylvanian
- Regional northwest-southeast, near vertical, open fracture system*
- Second order folds with amplitude of 15-100 ft and wavelength of 300-3000 ft*
- Fractures sealed with halite, anhydrite, clay, and calcite

*Grove and others 1993

QUESTIONS

1. Does thermal maturity and volume of oil generated account for production difference between Lisbon and Big Flat areas?
2. If both areas generated the same volume of oil, where is the oil in the Lisbon area?
3. Is production dependent on structure, if so, are the structures in the Big Flat area better developed than in the Lisbon area?
4. Are sweet spots in the Green River and Lisbon areas still waiting to be found?
5. How much does reservoir thickness (dolomite and dolomitic siltstone) influence production?
6. Does the dolomite diagenesis in the siltstone/sandstone beds pre-date or post-date oil generation?
7. If dolomite diagenesis post-dates oil generation could the siltstone/sandstone beds have provided pathways for long distance migration?
8. Do the sealed fractures pre-date or post-date the open-fracture system and oil generation?
9. If sealed fractures pre-date oil generation, why did they not open up again when the open fracture set developed?
10. If sealed fractures post-date oil generation, why did they not serve as pathways allowing oil to leak out?
11. What is the most effective artificial stimulation for the B interval?

FURTHER WORK

Detailed fracture study
- How fractures influence production

Fluid inclusion analysis
- Understand timing of fractures

Epifluorescence of cuttings and core
- Sweet spot identification

Geochemistry
- Maturity analysis

Detailed geomechanical characterization and well completion analysis
(Energy and Geoscience Institute, University of Utah)
- Cisco State 36-13
- Cane Creek 26-3
- Cane Creek 7-1